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MyOSD 2014: Evaluating Oceanographic Measurements Contributed by Citizen Scientists in Support of Ocean Sampling Day †

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The first Ocean Sampling Day (OSD) took place on June 21, 2014. In a coordinated effort, an internationally distributed group of scientists collected samples from marine surface waters in order to study microbial diversity on a single day with global granularity. Concurrently, citizen scientists enriched the OSD initiative through the MyOSD project, providing additional oceanographic measurements crucial to the contextualization of microbial diversity. Clear protocols, a user-friendly smartphone application, and an online web-form guided citizens in accurate data acquisition, promoting quality submissions to the project's information system. To evaluate the coverage and quality of MyOSD data submissions, we compared the sea surface temperature measurements acquired through OSD, MyOSD, and automatic *in situ* systems and satellite measurements. Our results show that the quality of citizen-science measurements was comparable to that of scientific measurements. As 79% of MyOSD measurements were conducted in geographic areas not covered by automatic *in situ* or satellite measurement, citizen scientists contributed significantly to worldwide oceanographic data gathering. Furthermore, survey results indicate that participation in MyOSD made citizens feel more engaged in ocean issues and may have increased their environmental awareness and ocean literacy.

INTRODUCTION

Ocean Sampling Day

Marine microbes are the most abundant life forms in the ocean (14) and are key players in biogeochemical cycles which influence marine, terrestrial, and atmospheric ecosystems (31). For example, marine phytoplankton are responsible for about half of Earth's primary production and are the foundation of the marine biological carbon pump (1). In the context of global climate change, the importance of these microbially mediated processes is a target of intensifying research (24). However, only about one to ten percent of microbes are currently culturable and amenable to laboratory study (12, 32). Therefore, culture-independent approaches, like amplicon or metagenomic sequencing, are popularly utilized to study the genetic potential and diversity of microbial communities in environmental samples. Both the throughput and cost-effectiveness of next-generation sequencing are increasing rapidly (22), promoting its use in microbial ecology. Such technology has enabled large sampling campaigns focused on exploring marine microbial diversity. Notable examples include the Global Ocean Sampling Expedition (GOS) (26), the Tara Oceans project (17), and the Malaspina expedition (11). These landmark expeditions gathered samples from the global ocean across time periods ranging from ten months to three years. In contrast, the first Ocean Sampling Day (OSD) was a simultaneous, collaborative, global sequencing campaign to analyze microbial community composition and functional traits in the ocean's surface on a single day, June 21, 2014. All OSD procedures were designed to maximize comparability of the project's data and included the measurement of environmental parameters known to influence microbial ecology (18).

MyOSD: Citizen science meets marine microbiology

Citizen science (CS) involves the participation of the lay community in scientific research activities and often

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centers on the collection of data (30). Over the last few decades, CS has grown in popularity, and it is now regularly featured in conservation science. Citizen scientists have collected vast amounts of otherwise unobtainable data in support of time- and resource-limited research activities (10). The eBird project is one of the largest examples to date: a collection of 1.7 million bird observations has been amassed from more than 210 countries over a six-year period (34). Additionally, the American Gut (http://americangut.org/) and The Wild Life of Our Homes (3) are CS projects focusing on sampling microbes. Besides enabling data collection, CS has also enhanced the scientific literacy of citizens with no formal scientific training and influenced their attitudes toward environmental issues (5, 29).

MyOSD relies on public engagement and aims to 1) raise awareness of the importance of marine microbial life and its influence on humans, 2) provide citizens the opportunity to participate in a worldwide research event, and 3) create a CS community and infrastructure for future iterations of MyOSD. MyOSD initially focused on enabling participants to collect oceanographic data including important environmental parameters such as water temperature and salinity. These oceanographic data are not only crucial for the understanding of microbial biodiversity, but also for other research fields including climatology or meteorology. A wide range of systems collect oceanographic data at high spatial and temporal resolution: moorings, buoys, gliders, and research vessels measure environmental parameters at several water depths around the globe. Additionally, remote-sensing payloads on orbital satellites can measure temperature, salinity, and even chlorophyll concentrations across global surface waters. However, despite the deployment of several thousand measurement devices, only a small proportion of the global ocean is monitored at any given time (19). Further, temperature measurements from remote-sensing devices are limited to a thin layer of ocean water which corresponds to, or lies within, the sea surface microlayer: infrared systems report temperatures of a layer ~10-µm thick, while microwave systems are able to penetrate a few millimeters below the surface (27, 33). Moreover, the presence of clouds hampers measurements from orbit, leading to patchy coverage (15). Citizen scientists can help fill these gaps through their willingness to collect data *in situ*; however, it is essential that CS measurements are reliable.

To determine reliability of citizen-sourced oceanographic measurements, we compared sea surface water temperature measurements from MyOSD participants and OSD scientists to automatic *in situ* systems and satellite data. To contextualize this evaluation, we discuss the MyOSD questionnaire, which captured the perspectives and motivations of MyOSD participants. Overall, MyOSD represents one form of relatively cost-efficient approaches to complement existing oceanographic measurement systems, as already discussed by Lauro et al. (19).

METHODS

MyOSD: CS meets marine microbial ecology

Citizen scientists were asked to record multiple parameters at their sampling site(s) during the OSD sampling event. Time, date, geographic coordinates (longitude and latitude), GPS accuracy, sampling depth(s), sample name(s), air temperature, water temperature, wind speed, salinity, phosphate, nitrate, nitrite, pH, and Secchi depth readings were requested as well as descriptions of the environment, based on the Environmental Ontology (ENVO) (6) and weather conditions. These parameters were chosen by the OSD Consortium according to their scientific importance as well as their measurability with inexpensive and easily-available instruments. MyOSD operated with open membership without the need for prior registration. To ensure consistency and ease of data acquisition, the "OSD Citizen" smartphone application for Android and iOS was developed. This free application can be downloaded in the App Store and in the Google Play store (https://itunes.apple.com/us/app/osd-citizen/id834353532?mt=8, https://play.google.com/store/apps/details?id=com.iw.esa&hl=en). An online webform (http://mb3is.megx.net/osd-app/myosd-form)—featuring the same input fields as the application—was provided for participants who do not possess a smartphone. Both a text-based tutorial (www.my-osd.org/) and a video tutorial (www.youtube.com/watch?v=1lhDdPbzuTs) were created to demonstrate the measurement procedure and use of the OSD Citizen app. Additional material on marine microbes was contributed by NOAA's Ocean Explorer (http://oceanexplorer.noaa.gov/ocean-sampling-day/).

Only data concerning sampling time, date, geographic coordinates (longitude and latitude), GPS accuracy, sampling depth(s), and sample name(s) were required prior to submitting a MyOSD entry to the Micro B3 Information System (18). Application users also had the option to take pictures of their sampling activities. After submission, data were shown in near real time on the "OSD live" page (http://mb3is.megx.net/osd-app/samples). This open-access page shows the location of the samples on a world map as well as all measured data, which can be downloaded in comma-separated values (CSV) format.

All scientific participants submitted their OSD data using an online web-form. These data were recorded using paper-based log sheets, which scientists had to fill in and send to the OSD Consortium along with the biological sample.

MYOSD QUESTIONNAIRE

Participants were asked to give anonymous feedback about the MyOSD campaign and the OSD Citizen application via SurveyMonkey (www.surveymonkey.com/). The questionnaire was accessible both via the OSD Citizen application and through a link on the OSD live page for one week after the 2014 solstice. It included ten questions with multiple-choice or Likert-type scale (21) answers (Table 1) (Appendix 1).

Water temperature validation using *in situ* data

The submitted values for water temperature were validated by two different approaches, an *in situ* approach and a satellite-based approach. For the *in situ* approach, all datasets derived from *in situ* measurement systems available between June 20 and 21, 2014—as most MyOSD measurements were performed between those dates—were downloaded from the Coriolis Data Center (www.coriolis.eu.org/) on October 29, 2014. These data contained animal-profiles, Argo-profiles, XBT-profiles, CTD-profiles, glider-profiles, other-profiles, drifting-buoys, thermosalinograph (TSG), mooring-buoys-time-series, bottles and other time series or trajectories. Data within a radius of 1 km up to 10 km of each OSD and MyOSD measurements were used for comparison (Appendices 2 and 3).

Water temperature validation using remote sensing data

In the satellite-based approach, data from three different satellites—Aqua, Terra, and Aquarius—were used. NASA's Aqua and Terra satellites carry on board the Moderate Resolution Imaging Spectroradiometer (MODIS) for sea surface temperature (SST) measurements. The satellites' descending passes differ, with implications for the SST data they provide. Aqua's descending passes are in the afternoon (12:00 to 13:00) and at night (01:00 to 02:00), while Terra's are in the morning (9:00 to 10:00) and at night (20:00 to 21:00) (20). Aquarius, the first satellite sensor to measure sea surface salinity (SSS) as well as SST is a joint mission of NASA and the Argentinean Space Agency (CONAE).

The satellites' daytime Level-3 data products with full spatial coverage at 4 km resolution giving the mean SST temperature over 12 hours were downloaded from different sources: SST data from Aqua, Terra, and Aquarius (spatial resolution 100 km) were obtained from ftp://podaac-ftp.jpl.nasa.gov/OceanTemperature/modis/L3/aqua/11um/4km/daily/2014 on December 12, 2014, from ftp://podaac-ftp.jpl.nasa.gov/OceanTemperature/modis/L3/terra/11um/4km/daily/2014 on January 19, 2015, and from ftp://podaac-ftp.jpl.nasa.gov/SalinityDensity/aquarius/L3/mapped/V3/daily/SCI/2014 on December 16, 2014, respectively. These websites are maintained by the NASA JPL Physical Oceanography DAAC, Pasadena, CA 2014.

Daily data between June 19 and 25, 2014, were downloaded to ensure the satellite-derived observations were

TABLE 1.
The MyOSD questionnaire.

What is your gender? ❒ Male ❒ Female
What is your age? ❒ 6–12 ❒ 12–18 ❒ 18–24 ❒ 25–34 ❒ 35–44 ❒ 45–54 ❒ 55–64 ❒ 65–74 ❒ 75 or older
How did you hear about MyOSD? ❒ Social media (Facebook, Twitter etc.) ❒ News, Blogs ❒ Friends, Colleagues ❒ Other please specify
Participate in MyOSD made me feel more engaged with ocean issues. ❒ Strongly agree ❒ Agree ❒ Neither agree nor disagree ❒ Disagree ❒ Strongly disagree
It was easy to understand how to participate in MyOSD. ❒ Strongly agree ❒ Agree ❒ Neither agree nor disagree ❒ Disagree ❒ Strongly disagree
Please tell us about any issues you experienced participating in MyOSD (e.g. issues while sampling or using OSD App). Free answer
I would like to participate in MyOSD next year again. ❒ Strongly agree ❒ Agree ❒ Neither agree nor disagree ❒ Disagree ❒ Strongly disagree
Where does your interest in the ocean come from? ❒ I live close to the sea ❒ I work in a ocean related field ❒ I have ocean related hobbies ❒ I was always interested in the ocean ❒ This was the first time I got engaged with ocean issues ❒ Other please specify
I participated in Citizen Science projects before MyOSD. ❒ Yes ❒ No
Do you have any other comments, questions, concerns or feedback? Free answer

separated from OSD and MyOSD observations by no more than 12 hours. We accepted OSD/MyOSD measurements between June 19 and 25, 2014. To compare the satellite-derived SST with the *in situ* SST measured during the OSD and MyOSD event, corresponding pairs of cloud-free, co-located satellite and *in situ* SST observations were produced (Appendices 2 and 3). These corresponding pairs were identified using the program SeaDAS Version 7.1 (2) via its Pixel Extraction tool. Only boxes of "1 × 1" pixel were extracted (2). The calculations of the root-mean-square error (RMSE) and plots were done with R 3.0.1 (25) including the packages HydroGOF version 0.3-8 and ggplot2 version 0.9.3.1.

RESULTS AND DISCUSSION

MyOSD sample submissions

In total, we received 61 data uploads from MyOSD participants. All but nine measurements were performed in marine water bodies. Varying proportions of participants measured water temperature (89%), air temperature (69%), wind speed (53%), pH (51%), salinity (48%), nitrate (36%), Secchi depth (25%), phosphate (23%), and nitrite (2%) (Table 2). As some participants shared one MyOSD user account, we are unsure of the exact number of individual participants. However, based on participant pictures and personal communications, we estimate that at least 100 people joined MyOSD. This is a relatively low number compared with CS projects that involved tens of thousands of contributors working from their homes, such as Foldit (7), with 50,000 users in a period of five months, and Galaxy Zoo, in which volunteers classified 900,000 galaxies from pictures of the Sloan Digital Sky Survey (SDSS) within seven months (13). Other CS projects focusing on microbial sampling have engaged thousands of people: the American Gut (http://americangut.org/) obtained samples from 3,328 people, and The Wild Life of Our Homes (3) obtained 1,430 microbial dust samples. Several points may account for this stark contrast in participant numbers: first, the MyOSD project is part of the larger scientific EU project Micro B3 (www.microb3.eu/) and, in contrast to the dedicated CS projects, represents more of a pilot project into citizen science. Hence, the coordination team was comparably small, and the time spent on outreach activities was limited. In order to reach out and build up an engaged community, more time is needed to spread the word and spark interest in the project. Second, marine microbiology and oceanography are fields which do not have large numbers of hobbyists in comparison with astronomy or ornithology, complicating the recruiting of volunteers (13). Third, the American Gut and The Wild Life of Our Homes projects asked volunteers to sample their own body or home; MyOSD, on the other hand, required participants to sample remote locations. A further challenge was that the MyOSD sampling event occurred on a single day; therefore, participants had to concentrate their efforts—which included equipment acquisition, transport, and the measurements themselves—in such a manner that may have discouraged wider participation. Although we accepted measurements from June 19 to 25, 2014, the majority of submissions (51) were reported on June 21, 2014. A more comparable project is the Secchi App (www.secchidisk.org/), which follows a similar approach. This project collects Secchi disk measurements to determine global phytoplankton concentrations in the ocean. Participants must build their own Secchi disk, travel to a body of water, and submit their observations via a smartphone application. This project collected 309 submissions worldwide over a period of about 18 months (February 23, 2013–June 15, 2014) (28). Thus 61 MyOSD sample submissions in a period of five days can be considered a promising start.

TABLE 2.
Number of measurements for each parameter included in the MyOSD submission form.

Parameter	Submitted
Water temperature	54
Air temperature	42
Wind speed	32
pH	31
Salinity	29
Nitrate	22
Secchi disk	15
Phosphate	14
Nitrite	1

A total of 61 submissions were collected.

Perspectives of MyOSD citizen scientists

The citizen scientists were asked to give feedback in an anonymous survey. To keep the burden low and increase the willingness to complete the survey, it contained only ten questions (Table 1) (8). Our aim was to develop an understanding of our citizen scientists, how MyOSD influenced them, and what they liked or disliked. This is a first step toward creating effective engagement and educational tools for our new CS community.

With a total of 47 people (77% response rate) completing the questionnaire, the survey can be considered successful relative to most other online surveys (4). Of the respondents, 47% were female and 53% male with ages from 6 to 12 years (2%) up to 55 to 64 (11%). Most participants were 25 to 34 years (34%), followed by 45 to 54 (19%), 35 to 44 (15%), 18 to 24 (13%) and 12 to 18 (6%). Only 13% stated they heard of MyOSD from news and blogs, 19% via social media (e.g., Facebook), and 21% answered "other" and specified that they heard about MyOSD, for example, on school trips, at workshops or in university. Interestingly, the majority of participants was informed by friends or colleagues (28%). In total, 17% of the participants had taken part in CS projects before MyOSD, and 64% were doing it for the first time.

Most of the participants strongly agreed (30%) or agreed (53%) with the statement "Participating in MyOSD made me feel more engaged with ocean issues," and only 2% neither agreed nor disagreed. Also, most citizen scientists strongly agreed (17%) or agreed (51%) with the statement "It was easy to understand how to participate in MyOSD," while 17% neither agreed nor disagreed. When asked if they would like to participate in MyOSD the following year, 40% and 34% strongly agreed and agreed, respectively, while 9% neither agreed nor disagreed. We asked the participants to state what motivated their interest in the ocean. Most participants stated that the proximity of their home to the sea motivated them (40%); those working in an ocean-related field composed the second-largest group (34%). A smaller group (28%) stated a pre-existing interest in the oceanic ecosystem, while only 15% had ocean-related hobbies. A total of 15% stated other reasons, mainly involving family and children ("I like my daughter to get interested in science," "My Father [sic]"). For 9% of participants, MyOSD was their first engagement with ocean issues.

When we asked for feedback on the MyOSD campaign, people were mainly interested in "doing more," especially taking water samples for microbial investigations themselves or being able to order test kits ("I would love to be able to collect a sample to be tested for bacterial DNA and this was not an option for me at this point." "It would be good if we could do more. You could offer test kits etc. that we could buy.")

This survey provided us with an impression of the audience we reached and their perspectives. Due to time and cost limitations our outreach was mainly based on social media like Facebook and Twitter, as well as CS platforms and some personal outreach activities like presentations or information booths. Due to this web-based outreach we expected to reach mainly digital natives (born after 1980) (23) who already have a connection to the ocean. This is in fact reflected in the participants' age distribution, with 55% being under 35 years. Interestingly, social media tools (19%) provided good platforms to keep participants up to date, but for recruitment, personal communication from friends and family (28%), as well as workshops and university outreach (21%), was apparently more effective for MyOSD. This indicates that, should all other aspects be held constant, direct and personal communication is likely to yield the most participation. We were encouraged to see that MyOSD attracted citizens with no prior CS experience (64%) and made the majority (83%) feel more engaged with marine issues. We hope that this has positively influenced environmental behavior and ocean literacy (5, 29), and future MyOSDs may evaluate this more closely. Although the majority (68%) agreed that MyOSD had an approachable concept, participants reported that the OSD Citizen application and the sampling procedure were too complicated. We responded to these issues via personal communication with participants, improved the usability of the OSD Citizen application, and made the principles of MyOSD clearer for future CS projects.

Validation of MyOSD water temperature measurements

We chose to validate the SST measurements submitted by MyOSD participants against proximate values obtained from satellite-based sensors and *in situ* sensors. Sea surface temperature was chosen as it was the nonmandatory parameter that was most frequently reported by MyOSD participants (Table 2) and a mandatory measurement for OSD participants.

None of the citizen sampling was performed within 10 km of any of the *in situ* systems. Hence, we could not do any comparison. Similarly, Aquarius satellite data either did not correspond to MyOSD measurement sites or was unavailable due to cloud cover.

We obtained a small number of suitable readings from the Aqua and Terra satellites (Tables 3 and 4). We only included OSD and MyOSD *in situ* temperature measured between 0 and 1 meters or 0 and 4 meters of depth due to the depth limitation of satellite measurements (27, 33). All MyOSD SST measurements corresponding to a satellite SST measurement, except one, were made above or at 5 meters' depth (Table 5). It is difficult to compare *in situ*, nonautomatic measurements performed by different people using different devices at different depths with the daily mean of MODIS SST data. For this reason, and also due to the low number of MyOSD and satellite SST measurement pairs (ten individual measurements or 21%) compared to OSD and satellite SST measurement pairs (57 individual measurements or 44%), our approach was the following: We compared OSD data measured by scientists with satellite data measured at each sampling location and calculated the RMSE. For both the Aqua and Terra satellites, the RMSE for measurements performed at 0 to 5 meters was higher (1.41°C and 1.65°C, respectively) than that of the 0- to 1-meter measurements (1.15°C and 1.45°C, respectively) (Table 5). This reflects our expectations, as the temperature on the sea surface microlayer may differ due to the influence of direct solar radiation, especially under low wind conditions. Therefore, we expect the RMSE to increase when deeper water samples are included (9). Several studies have tried to validate the MODIS SST observations used by Aqua and Terra. The lowest RMSE was observed in the western north Pacific for the Aqua satellite (0.70°C for Aqua 0.65°C for Terra) (16). Lee et al. obtained an RMSE of 0.88°C for Aqua and 0.71°C for Terra (20) while Delgado et al. obtained an RMSE of 0.95°C for Aqua (9). These RMSEs are lower than the ones found in our study. Each of these studies had more *in situ* SST data collected over a longer period of time in a more restricted oceanic area: Delgado et al. performed 266 *in situ* SST measurements over a period of 11 months at 43 stations

TABLE 3.
Comparison of MyOSD *in situ* sea surface temperature measurements (SST) and cloud-free Terra satellite SST measurements.

ID	Sample name	Terra SST (°C)	*in situ* SST (°C)	Sampling depth of *in situ* SST measurement (m)	Difference in SST (°C)
A	Bart – 1	17.61	19	0	-1.39
B	Manfred – 2	15.57	15.4	0.8	0.17
D	Johanna – 30	17.28	17.15	1	0.13
H	RCERR – Northeast end of Town Marsh	27.16	28.14	1	-0.98
C	Tegla	20.67	21.2	1	-0.53
I	RCERR – South side of Horse Island	25.28	28.45	1	-3.17
J	MarineLab – 1	28.77	26	3	2.77

The sampling depth of *in situ* measurements and the difference between the SST data is also presented.
OSD = Ocean Sampling Day; SST = sea surface temperature.

TABLE 4.
Comparison of MyOSD *in situ* sea surface temperature measurements (SST) and cloud-free Aqua satellite SST measurements.

ID	Sample name	Aqua SST (°C)	*in situ* SST (°C)	Sampling depth of *in situ* SST measurement (m)	Difference SST (°C)
A	Bart – 1	17.67	19	0	-1.33
B	Manfred – 2	15.75	15.4	0.8	0.35
C	Tegla	20.82	21.2	1	-0.38
D	Johanna – 30	17.49	17.15	1	0.34
E	Clare nina – 1	15.17	16	1.09	-0.83
F	Johanna – 5	16.41	16	3.1	0.41
G	Justin, Debra, Hayley, and Riley – 1	21.44	21	5	0.44

The sampling depth of *in situ* measurements and the difference between the SST data is also presented.
OSD = Ocean Sampling Day; SST = sea surface temperature.

along the inner and mid-shelves of the southwest of Buenos Aires Province (9). These studies focused on the evaluation of the satellite products; therefore, they considered factors such as the times satellites crossed and wind speed to calculate an accurate bias and RMSE. In our study, we did not evaluate MODIS itself, but used the RMSE to compare the accuracy of measurements performed by scientists with the satellite data we acquired. We also used the RMSE to assess whether CS data are in the same range of accuracy.

Figures 1 and 2 show the MyOSD *in situ* temperature and the corresponding SST measured by the satellite (Table 5). If a MyOSD *in situ* measurement falls within the error range, the measurement is within the range of those performed by scientists and we consider it trustworthy. In panel A (Fig. 1), three of the four *in situ* measurements are within the RMSE and can be accepted as trustworthy. Sample A, however, is slightly (0.18 °C) outside the error range. In panel B (Fig. 1) the sample depth range is increased to 5 m. This results in a higher RMSE and all seven samples are found within the error range. Interestingly, sample A is a surface measurement and we would have expected samples taken from greater depths to differ more from the satellite measurements.

Panel C (Fig. 2) shows that all of the MyOSD *in situ* measurements are within the RMSE except sample I. Further, in panel D (Fig. 2), sample I is still high above the RMSE (1.56°C) and is thus suspect. A deeper sample, J, was observed outside of the RMSE with an SST value 1.16°C lower than the Terra measurement. Sample J was taken in a depth of three meters near Florida. Accounting for the influence of tropical radiation on the sea surface microlayer, the temperature difference is not considered suspect. In total, we have ten individual MyOSD SST measurements of areas which were also covered by satellite sensors. Nine of these measurements seem to represent trustworthy values compared with the RMSE calculated from OSD measurements. Additionally, half of the measurements fall within the stringent RMSE range of 0.7°C (Terra) and 0.65°C (Aqua) determined by Hosoda et al. (16).

TABLE 5.
Number of cloud-free SST measurements from the Aquarius, Aqua, and Terra satellites that correspond to OSD and MyOSD *in situ* measurements (i.e., "data pairs").

OSD: Total number of sampling locations up to a sampling depth of 5 m: 131

Satellite	Depth	Data Pairs[a]	RMSE (°C)
Aquarius	1 m	2	NA
Aquarius	5 m	2	NA
Aqua	1 m	28	1.15
Aqua	5 m	41	1.41
Terra	1 m	23	1.45
Terra	5 m	41	1.65

MyOSD: Total number of sampling locations up to a sampling depth of 5 m: 47

Satellite	Depth	Data Pairs[a]
Aquarius	1 m	0
Aquarius	5 m	0
Aqua	1 m	4
Aqua	5 m	7
Terra	1 m	6
Terra	5 m	7

[a] The column "Data Pairs" shows the number of OSD or MyOSD measurements at 0–1 meters or 0–5 meters that were *also* measured by a satellite. The RMSE of OSD measurements was used to judge the accuracy of MyOSD measurements.

SST = sea surface temperature; OSD = Ocean Sampling Day; RMSE = root-mean-square error; NA = not available due to insufficient sample size.

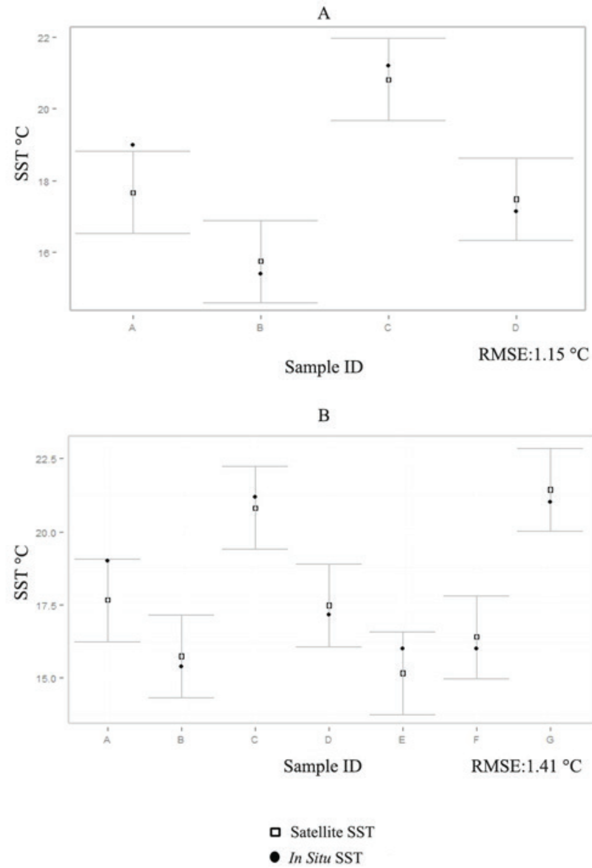

FIGURE 1. MyOSD *in situ* sea surface temperature (SST) measurements (filled circle) at a depth of 0–1 meters (A) and 0–5 meters (B). The corresponding Aqua satellite SSTs are shown as hollow squares. The error bars represent the corresponding RMSE calculated from OSD measurements. SST = sea surface temperature; RMSE = root-mean-square error; OSD = Ocean Sampling Day.

Although this set of MyOSD measurement is small, it does support the idea that volunteer-collected data agree with data collected by scientists. Further studies with greater size should be conducted to strengthen this hypothesis. This pilot study suggests that this form of data gathering is both valid and valuable. Moreover, 79% of MyOSD measurements were taken in geographic areas not covered by any of the *in situ* or satellite systems. This emphasizes the need for greater global coverage by these systems. Lauro et al. (19) previously discussed these issues and encouraged the inclusion of citizen scientists, especially sailors and retrofit sailboats, in a worldwide effort to collect oceanographic data and even microbial samples. Our results indicate that measurements of sea surface temperature data performed by citizen scientists are likely to be a suitable, cost-effective addition to global oceanographic measurements. The small but promising result set of MyOSD 2014 motivated us to repeat MyOSD in 2015. We equipped citizen scientists with sampling kits, allowing them to collect seawater samples for sequencing in addition to measuring oceanographic parameters. We are confident that the MyOSD campaigns will be instrumental in developing a CS community for marine microbiology.

While individual projects or project series may be of value in themselves, the issue of safeguarding CS data beyond the lifetime of such projects must be addressed. Current efforts, such as Citclops (www.citclops.eu/) or Secchi App, have developed infrastructures that may not be maintained after these projects end. MyOSD gives open access to all its CS data via the OSD live page (http://mb3is.megx.net/osd-app/samples), but cannot guarantee its persistence. Therefore, a sustainable future for CS rests upon centralized and persistent databases which contain marine CS data. This could save multiple stakeholders immense resources in accessing these data as well as secure the data from loss.

In summary, we were able to create a small but motivated global community of citizen scientists trained to collect trustworthy oceanographic data.

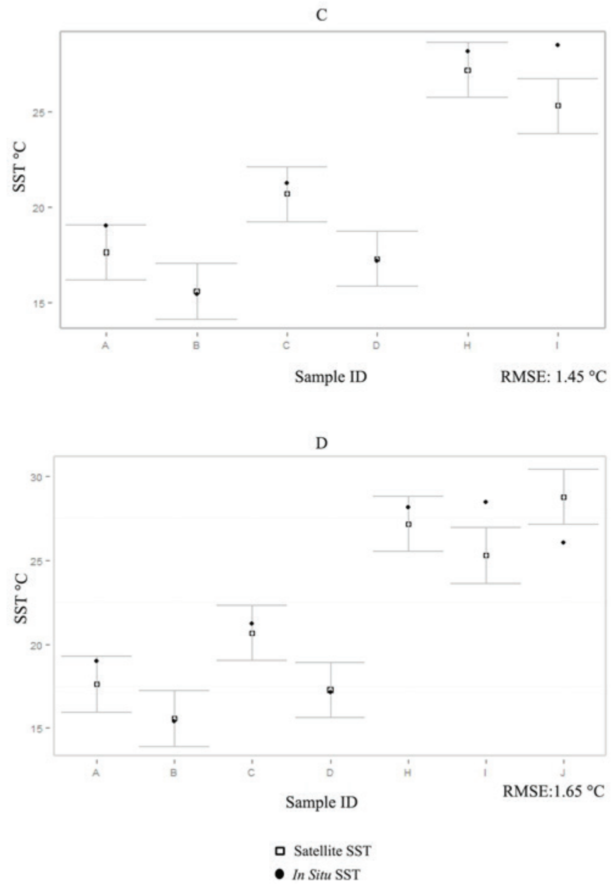

FIGURE 2. MyOSD *in situ* sea surface temperature (SST) measurements (filled circle) at a depth of 0–1 meters (C) and 0–5 meters (D). The corresponding Terra satellite SSTs are shown as hollow squares. The error bars represent the corresponding RMSE calculated from OSD measurements. SST = sea surface temperature; RMSE = root-mean-square error; OSD = Ocean Sampling Day.

SUPPLEMENTAL MATERIALS

Appendix 1: Answers to the MyOSD questionnaire
Appendix 2: MyOSD data used to locate corresponding SST data pairs with *in situ* measurement systems and satellite measurements
Appendix 3: OSD data used to locate corresponding SST data pairs with satellite measurements

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